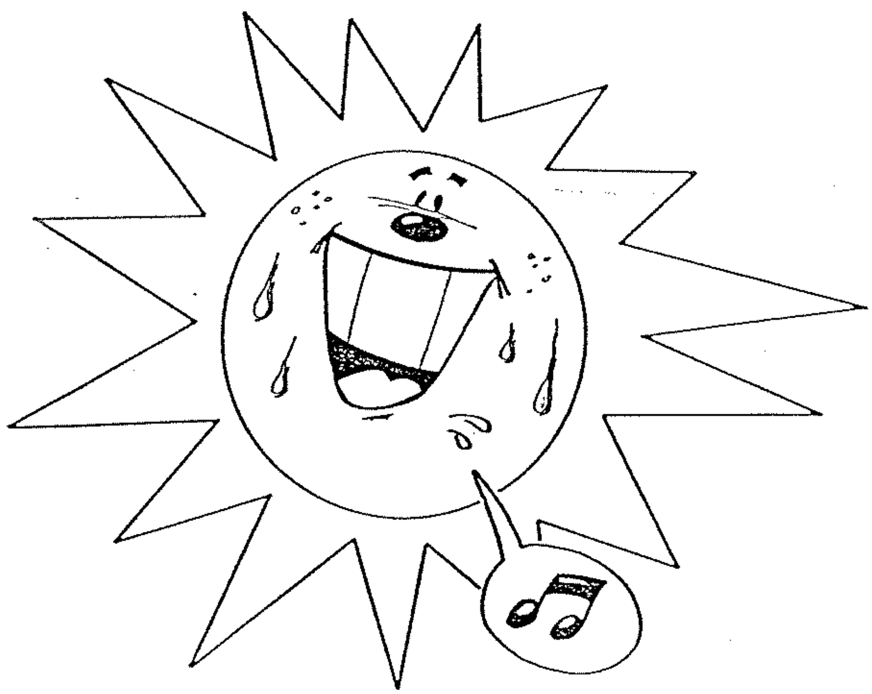
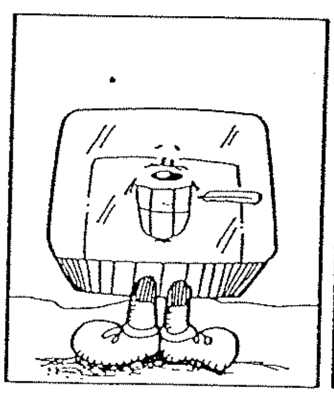
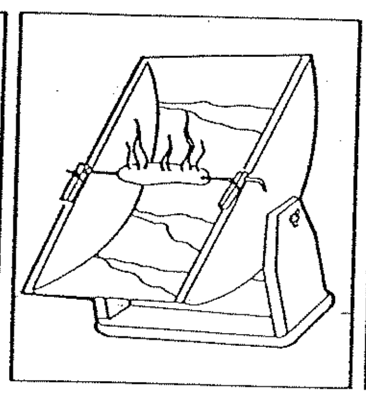
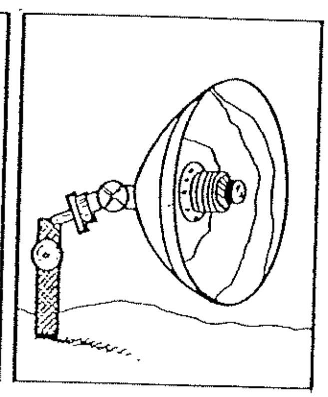
Capturing the Sun's Energy

Version 1









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Contents

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How to Build the Parabolic Trough Hot Dog Cooker

How to Build the Flat Plate Solar Collector

How to Obtain the Dish/Sterling System

Flash Cards

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Introduction

Welcome to the world of solar energy! These classroom exercises present.solar energy concepts from a hands-on point of view, and give the student an opportunity to handle lenses and perform experiments with a variety of models. The videotape shows how the models are used to demonstrate solar energy concepts.

Background

Energy is found in a variety of forms. It is seen in the motion of a car traveling down the street, stored in the gasoline that we buy at a service station; energy can also be felt in the warmth of the sun.

This booklet helps you investigate the sun's energy, which we receive as heat and light; this energy is called *solar energy*.

Vocabulary

There are many new words introduced in these experiments and activities. These words appear on the flash cards that are included in this package.

collector	magnifying glass
concentrator	reflective concentrator
Dish/Stirling engine	reflector
energy	refractive concentrator
Fresnel lens	refractor
Greenhouse Effect	solar energy
incline	

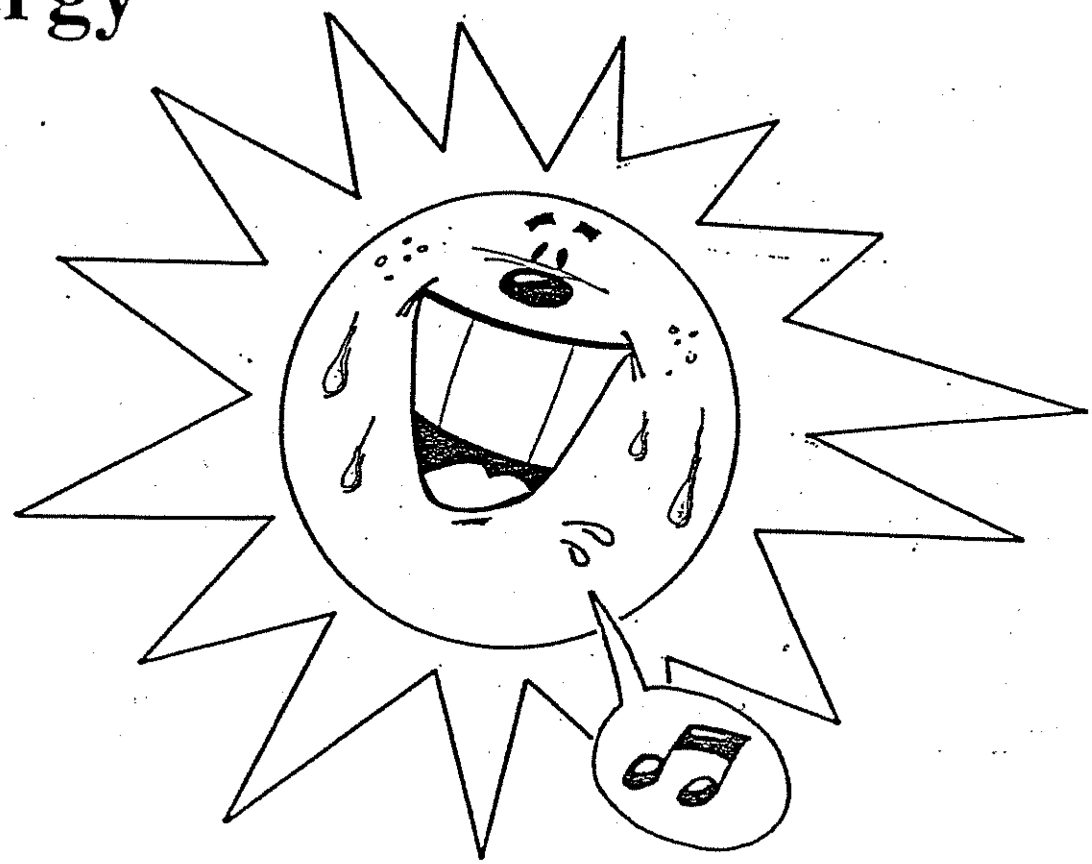
Processes

Observing
Comparing
Measuring
Collecting and analyzing
Inferring
Concluding
Discussing

Integration

Mathematics with measurement
Language arts with writing

Classroom Exercises for Capturing the Sun's Energy



Sandia National Laboratories

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Flat Plate Collector

Experiment #1

Does a covered collector heat up faster than an uncovered one?

Materials

- Two flat plate collectors
- Two metal meat thermometers (range 50° F to 180° F)
- Watch or clock

Hypothesis

Write what *you* think is true.

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Procedure

1. Remove the cover from one flat plate collector. Make sure that the cover on the other collector is securely in place and covers the entire opening.
2. On a sunny day, place the two collectors side by side outside on the ground and insert a thermometer in each one, under the metal plate. Make sure that the plates both have the same color face up and that the thermometers are placed in identical positions in both collectors.
3. Record the temperature that you observe in each flat plate collector in the data table. Record the temperature when you start and every 5 minutes afterward for 30 minutes.
4. Repeat the experiment on a calm day and a windy day; compare the results.

Data

Time (minutes)	Temperature (°F) Covered	Uncovered
0 (Start)		
5		
10		
15		
20		
25		
30		

Conclusions

What does your data tell you about collecting the sun's energy? Which collector, the covered or uncovered one, does a better job? What influence does the wind have?

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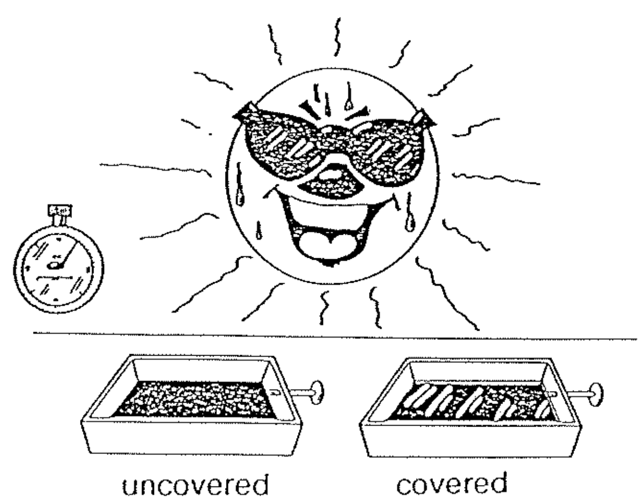

Flat Plate Collector

Experiment #2

Does a collector heat up faster with a white metal plate or a black metal plate inside?

Materials

- Two flat plate collector boxes, covered: one with a black face up metal plate, and one with a white face up metal plate
- Two metal meat thermometers (range 50° F to 180° F)
- Watch or clock

Hypothesis

Write what *you* think is true.

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Procedure

1. On a sunny day, place the two collectors side by side outside on the ground and insert a thermometer in each one, under the metal plates. One plate has its black face up and the other plate has its white face up.

2. Record the temperature that you observe in each flat plate collector in the data table. Record the temperature when you start and every 5 minutes afterward for 30 minutes.

Data

Time (minutes)	Temperature (°F) black	white
0 (Start)		
5		
10		
15		
20		
25		
30		

Conclusions

What does your data tell you about collecting the sun's energy? Which collector, the one with a white metal plate or a black metal plate inside, does a better job?

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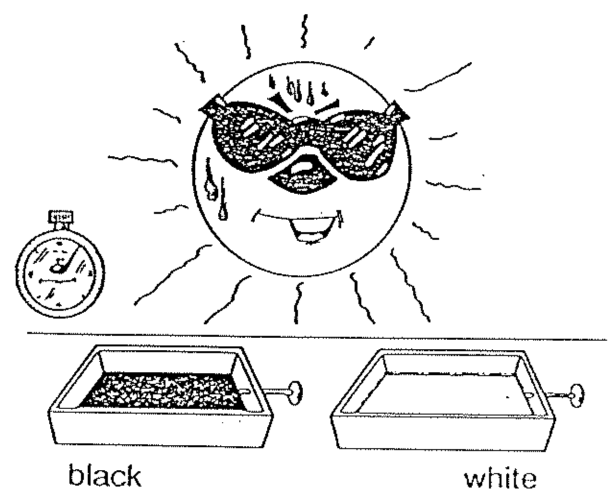

Flat Plate Collector

Experiment #3

Does the angle that a collector makes with the ground determine how fast the collector heats up?

Materials

- Four flat plate collectors
- Four metal meat thermometers (range 50° F to 180° F)
- Watch or clock

Hypothesis

Write what *you* think is true.

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Procedure

1. During the middle part of a sunny day, place four collectors side by side outside on the ground and insert a thermometer in each one, under the metal plate (make sure that the plates all have the same color metal plate face up and are covered entirely).

2. Let one collector remain flat on the ground. Using wood or books and a protractor, incline each of the three remaining collectors at a different angle. Record these angles on your data table (suggested angles are 0°, 15°, 30°, and 45°). Make sure that all the collectors are tilted up toward the sun.

3. Record the temperature that you observe in each flat plate collector in the data table. Record the temperature when you start and every 5 minutes afterward for 30 minutes.

4. Repeat the experiment at different times of the year, such as September, December, and May; record and compare the results.

Data

Time (minutes)	Temperature (°F) At Angle # 1=0°	2= °	3= °	4= °
0 (Start)				
5				
10				
15				
20				
25				
30				

Conclusions

What does your data tell you about collecting the sun's energy? At what angle does the collector do a better job? How do the collectors perform at different times of the year? What does this tell you about the importance of the tilt?

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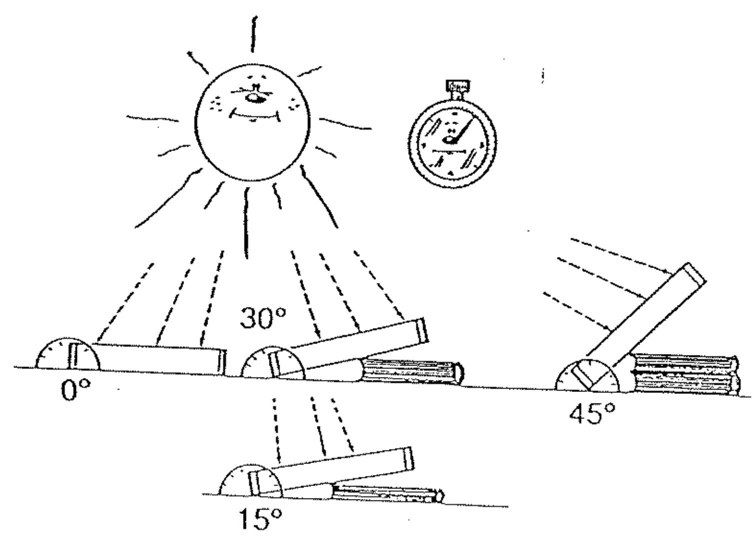

Refractive Concentrators

Experiment #1

Is a magnifying glass or a Fresnel lens better at concentrating light?

Materials

- Hand-held magnifying glass (make sure it is about the size of the Fresnel lens)
- Small Fresnel lens (make sure it is about the size of the magnifying glass). Fresnel lenses can be purchased through most educational materials catalogs.
- Bucket of water (1 to 2 gallons) or active garden hose
- Two pair of leather work gloves or oven mitts
- Paper

Hypothesis

Write what *you* think is true.

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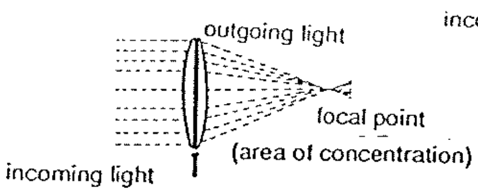
CAUTION:

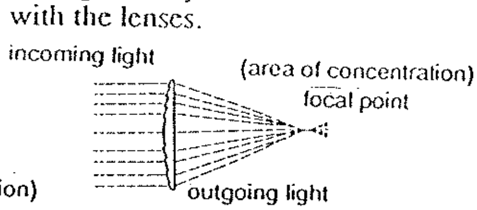
- Always use the water to completely extinguish the fire on the paper at the end of the experiment
- Always wear gloves.
- Keep observers at a safe distance.
- ***Do not* allow students to play with the lenses (such as focusing sunlight on themselves or each other).**

Procedure

1. Choose an outdoor location in an open area that has no nearby combustible materials. Make sure that the bucket of water or hose is nearby so that you can extinguish any small fire that you make with the lenses.



Magnifying glass



Fresnel lens

2. On a sunny day, set the paper and lenses in sunlight.
3. Select two students and have them put on the gloves or mitts. Give one the magnifying glass and the other the Fresnel lens. Have them both focus the lenses on the paper at same time.
4. Record which paper burns first as a result of this trial.
5. Repeat these steps at least three more times and record what happens each time in the data table.

Data

Trial	Quickest burn (magnifier or Fresnel)
1	
2	
3	
4	

Conclusions

What does your data tell you about concentrating the sun's energy? Which lens, the magnifier or Fresnel, burns the paper more quickly?

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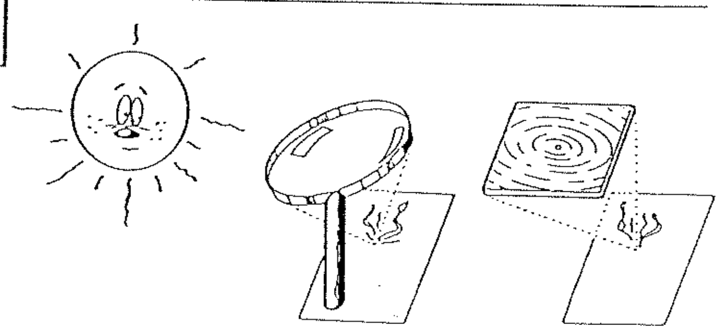

Refractive Concentrators

Experiment #2

Is a larger magnifying glass better at concentrating light than a smaller one?

Materials

- Hand-held 3-inch (or larger) magnifying glass
- Black or dark heavy construction paper or cardboard (1 sheet)
- Black or dark lightweight paper (1 sheet)
- Scissors
- Watch or clock
- Bucket of water (1 to 2 gallons) or active garden hose
- One pair of leather gloves or oven mitts

Hypothesis

Write what *you* think is true.

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CAUTION:

- Always use the water to completely extinguish the fire on the paper at the end of the experiment.
- Always wear gloves.
- Keep observers at a safe distance (5 to 10 feet away).
- ***Do not* allow students to play with the lenses (such as focusing sunlight on themselves or each other).**

Procedure

1. Choose an outdoor location in an open area that has no nearby combustible materials. Make sure that the bucket of water or hose is nearby so that you can extinguish any small fire that you make with the lenses.
2. On a sunny day, set up the lightweight paper and lens in sunlight to find the best position to make the paper burn. Record the time it takes in the data table.
3. Cut a 2-inch hole in the construction paper and cover the lens with the paper so that the hole is over the lens (this turns the larger lens into a smaller one).
4. Repeat Step 1. Now how long does it take for the paper to burn?
5. Repeat these steps with different sized holes.

Data

Hole size	Time to burn (seconds)
Uncovered	
2-inch	
1-inch	
1/2-inch	

Conclusions

What does your data tell you about concentrating the sun's energy? Which lens, the larger or smaller, burns the paper more quickly?

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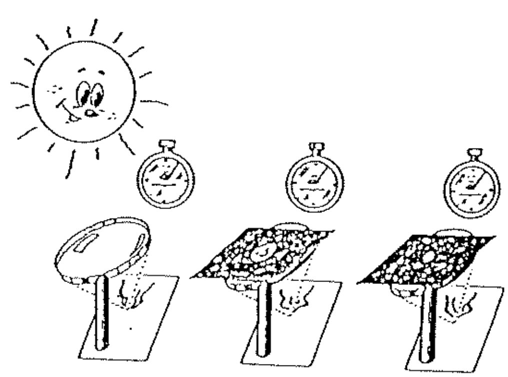


Refractive Concentrators

Activity

In this activity, you will compare a magnifying glass and a Fresnel lens. Fresnel lenses can be purchased through most educational materials catalogs.

To the teacher: *Do this activity indoors to avoid accidental burning.*

Set out magnifying lenses and Fresnel lenses for the students to handle. Remind the students that these refractive concentrators let light pass through them and bend the light rays as they come out to make them come together at a focal point.

To the student: Look over, handle, and touch the surfaces of the two types of lenses. Then answer the following questions.

1. Tell what you think each lens is made of.

   The magnifying lens seems to be made of____________________________

   The Fresnel lens seems to be made of ____________________________

2. Compare the surface of the magnifying lens to the surface of the Fresnel lens.

   ____

   ____

3. Describe a Fresnel lens so that someone looking at a pile of different things could pick out the Fresnel lens in the pile.____________________________

   ____

4. How do you think the magnifier could be improved?________________________

   ____

5. What kind of problem would a much larger magnifier have?____________________

   ____

6. Why is a plastic Fresnel lens probably better to use than a glass one?

   ____

Reflective Concentrators

Activity #1

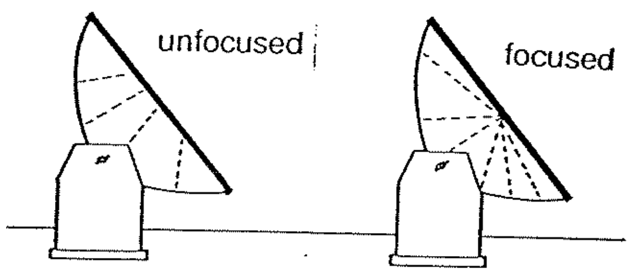
In this activity, you will cook hot dogs with energy from the sun using a reflective concentrator. You, the teacher, or another adult will perform all steps in this activity; do not allow students to play with this device.

CAUTION:	The concentrator creates high temperatures and very bright light at the focus. Make sure that you or another adult wear heat-proof gloves while demonstrating the model. All other observers should be kept at a safe distance (5 to 10 feet away).

To the teacher:

1. *You or another adult will perform this activity; do not allow students to play with this device.* On a very clear and calm day (around noontime), set the hot dog cooker on the ground facing the sun. (On a cold day, this activity can be done indoors near a large window.)

2. Loosen the nut and adjust the position of the reflective trough. Look at the light ray pattern on the inner edge of the trough; for best concentration, the sun's rays should come together and be visible on both wooden sides as shown in the videotape.

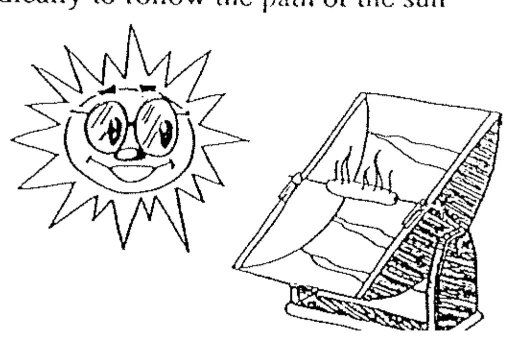


3. Place the metal skewer across the front of the solar cooker (secure the skewer in the clothespins). The skewer will seem very bright when the trough is aimed at the sun. Let the skewer preheat for about 30 to 60 seconds.

4. During the warm-up period, talk to the students. You can tell them that this is a reflective concentrator, and that the sunlight striking the curved reflective surface bounces off and shines on the skewer, which heats it up.

   Let the students look at their reflections in the curved reflective surface from a safe distance. Do not let the students look directly at the surface near the focal line; it can be dangerous.

5. With hands protected by heat-proof gloves, insert the preheated skewer into the hot dog and place the skewer back on the cooker. If you have time or have just a few students, lunch may be cooked in this manner. Depending on the strength of the sunlight, it may take 2 to 8 minutes to cook the hot dog. You may want to turn the hot dog periodically so that it cooks evenly on all sides. Remember that you will have to move the cooker periodically to follow the path of the sun to keep it focused properly.



Reflective Concentrators

Activity #2

In this activity, you will use a dish/Stirling engine. You, the teacher, or another adult will perform all steps in this activity; do not allow students to play with this device.

CAUTION:	The concentrator creates high temperatures and very bright light at the focus. Make sure that you or another adult wear heat-proof gloves while demonstrating the model. All other observers should be kept at a safe distance (5 to 10 feet away).

To the teacher: Let students examine the dish Stirling engine. An engine converts energy into motion; the dish Stirling engine converts solar energy into motion.

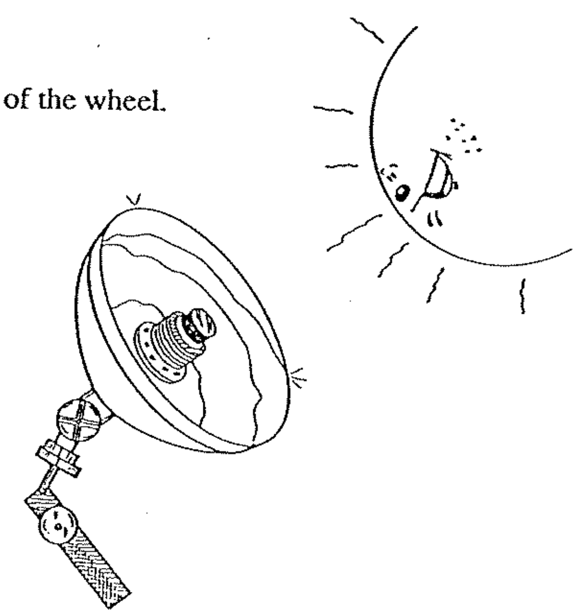
Identify:

1. The reflective surface, which is called a dish reflector.
2. The surface upon which the light will focus (this will be heated up).
3. The wheel behind the reflective dish, which will move.

With hands protected by heat-proof gloves, the teacher or another adult should hold the dish as shown in the videotape and aim the dish toward the sun. When the dish is properly aimed, the central spot in the dish will shine brightly.

Spin the wheel to start the engine working.

Change the aim of the dish and observe changes in the speed of the wheel.



Glossary of Key Terms

Collector	Something that receives or accepts; a solar collector receives the sun's rays.
Concentrator	Something that moves things closer together; a solar concentrator moves the sun's rays closer together.
Dish/Stirling System	A curved reflector that concentrates the sun's rays and changes the solar energy in them into the movement of a wheel.
Energy	Anything that causes or can cause work to be done, such as motion or a change in motion.
Flat plate collector	A receiver of the sun's rays that is flat and is usually covered with transparent material.
Fresnel lens	A piece of glass or plastic that has a grooved pattern on one side so that it will bend light rays to a focus. The bending of the light rays can make an object behind the lens appear larger.
Greenhouse Effect	An increase in temperature at the Earth's surface that is caused by the sun's warmth being trapped beneath a layer of transparent gases and material (like the glass or plastic windows of a greenhouse) in the atmosphere.
Incline	The angle between two objects, such as the angle between a flat plate collector (that is propped up) and the ground.
Magnifying glass	A curved piece of glass or plastic that can bend light rays to a focus. The bending of the light rays can make an object behind the lens appear larger.
Reflective concentrator	Something that moves light rays closer together as they bounce off (reflect from) its surface.
Reflector	Something that light bounces off of, such as a mirror or a shiny table.
Refractive concentrator	Something that moves light rays closer together as they bend (refract) while they pass through it, such as a magnifying glass.
Refractor	Something that causes light rays to bend as they pass through it. The bending depends on the material (glass or plastic, for example) or the shape of the material (flat or curved, for example).
Solar energy	The energy given off by the sun in the form of heat and light.

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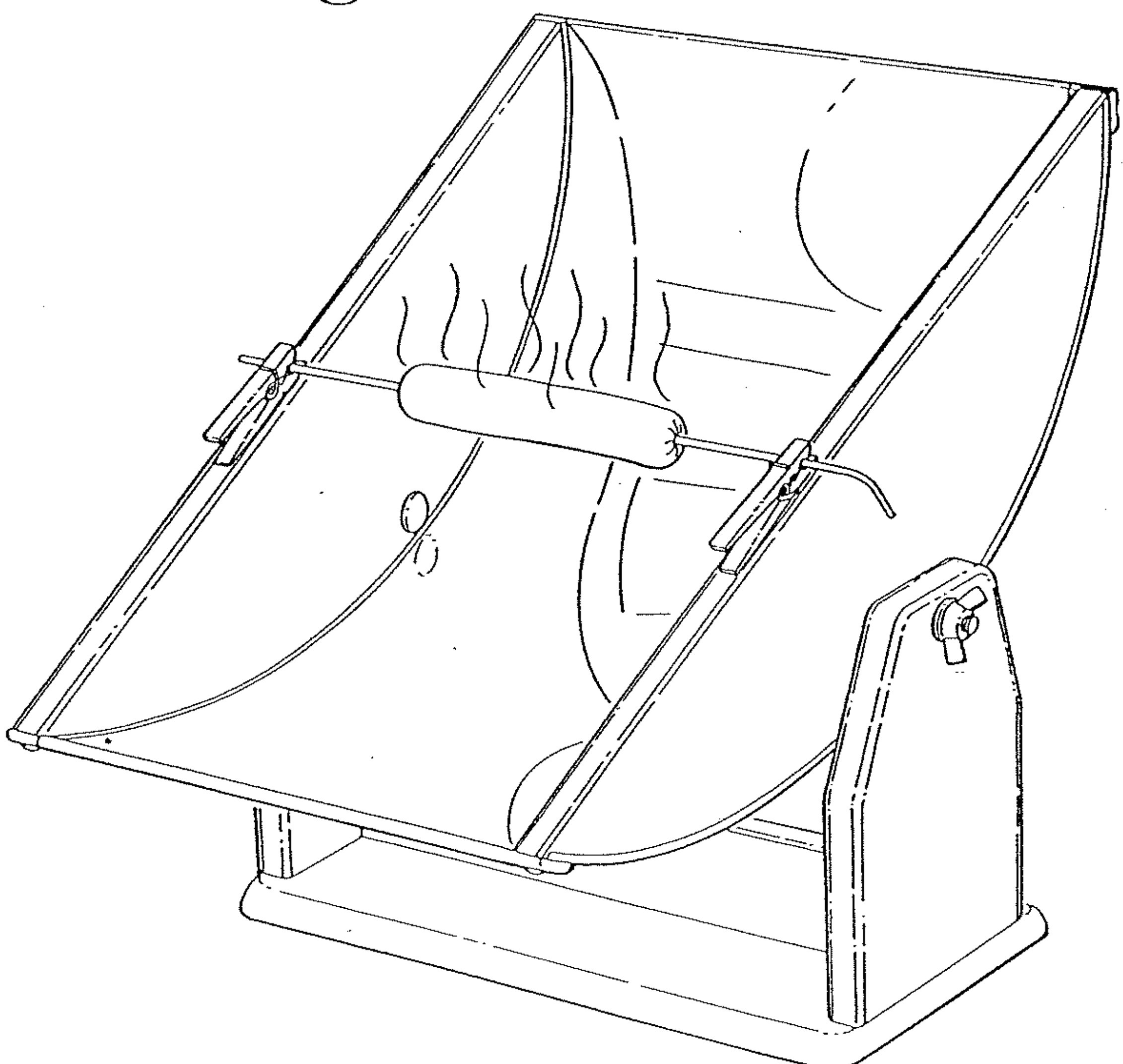
How to Build the Parabolic Trough Hot Dog Cooker

How to Build the Flat Plate Solar Collector Model

How to Obtain the Dish/Stirling System

How to Build the Parabolic Trough Hot Dog Cooker Model



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Background

The hot dog cooker model demonstrates a parabolic reflective solar concentrator. The model consist of a wooden trough that is lined with a highly reflective material and pivots on a wooden base. The model also includes a steam tube. For the classroom exercises, you will also need a hot dog, a skewer, and some water.

How it works

When you aim the trough directly at the sun on a clear day, the reflective material reflects some of the sun's rays into a single line (the focal line) that runs across the center of the trough. In a few minutes, the sun's rays can heat up water in the copper tube to produce steam or cook the hot dog on a skewer.

What you will need to build it

Materials

Wood

4-quarter or 1-inch nominal (1 x 6 or 1 x 3) pine or any medium hardness wood that is easy to cut

One 1 x 6 piece at least 56 inches long, or several pieces from which you can cut 2 pieces 20 inches long and 2 pieces 7 inches long

One 1 x 3 piece at least 13 inches long

One 2 x 4 piece at least 12 inches long

A piece of screen door molding or a 1/4 x 3/4 piece of wood that is at least 25 inches long

A piece of 7 x 13-5/8 x 3/4 plywood

Metal

Sheet metal (16 to 18 gauge, or no thicker than the cardboard backing on a pad of paper) least 12 x 24

Tools

Keyhole saw, band saw, scroll saw or jigsaw

Radial arm saw, table saw, or hand saw

Electric drill or hand drill with
- 1/4-inch diameter drill bit
- 3/32-inch diameter drill bit

Steel tape measure and carpenter's square

24-inch long ruler or straight edge, and pencil

Goggles or safety glasses, disposable dust mask, heavy work gloves

Tin snips or sheet metal shears
Metal file and large common nail

What you will need to build it (continued)

Materials	*Tools*
Screws	
Four #4 panhead wood screws, 3/4 inch	Screwdriver to match screw head
Seven 1/2-inch drywall or #4 or #6 wood screws	Phillips screwdriver or screwdriver bit for your drill
Nails	
About 2 dozen 3/4-inch flat-headed box nails (4 or 6 penny)	Hammer
Four 1-1/2–inch long finishing nails (6 or 8 penny)	Small wallpaper roller
Ten 1-1/2–inch long finishing nails	Nail set or large common nail
Bolts	
Two 1/4 x 2-inch carriage or hex head bolts with a star washer	Wrench or pliers
Nuts	
One 1/4-inch hex nut	
One 1/4-inch wing nut	
Washers	
Two 1/4-inch flat washers	
Sandpaper	
One sheet of medium grit	
Reflective Material	
Self-adhesive (two 10 x 13 pieces) Aluminized Mylar Self-adhesive reflective film	Hobby knife, X-Acto knife,wallpaper knife, or single-edge razor blades
Other (six 10 x 4-1/2 pieces) Hallmark gift wrap Aluminum foil	(If you are using self-adhesive material) Spray bottle filled with about 2 or more cups of water and a few drops of detergent (such as dishwashing liquid)
	Small wallpaper roller
Adhesives	
Small tube or 1/2 pint of Liquid Nails®	Small putty knife

Optional: If you are *not* using self-adhesive material, you will need the following:

1/2 pint rubber cement	1-inch wide soft paint brush

What you will need to build it (continued)

Materials	*Tools*
1/2 pint rubber cement thinner	

Tape

1 roll of 3/4-inch wide black plastic tape	Scissors
1 roll of clear or masking tape (any size)	Ball-point pen

Miscellaneous

12-inch (at least) skewer	
18-inch long piece of 1/4-inch diameter flexible copper tubing	Hacksaw or tubing cutter
2 wooden or plastic clothespins, or alligator clips	Flat black enamel paint

Optional: Finishing Materials

One pint of polyurethane varnish	2-inch wide paint brush

Optional: If you plan to countersink the screws (or nails), you may want to use some plastic wood filler or carpenter's putty to make the surface flush.

Have all your materials ready when you start. You may or may not need everything on the previously mentioned list; it depends on what methods and materials you prefer to use to make your cooker. Make sure you have this instruction and the pattern template for transferring the parabolic shape to the wood for the trough sides.

How to build it

> WARNING: Use goggles or safety glasses and a dust mask whenever you are cutting wood, especially with a power saw.

Cutting the Parts

Using Figure 1 as a guide–pg 8(and Figure 2 to see how the parts will fit together), cut the following parts:

1. For Part 1, select a piece of 1 x 6 stock of sufficient length to cut two pieces 20 inches long. These two pieces will become the trough sides.

2. Take the parabolic contour pattern (pg 11) and cut along the curve as shown in Figure 3 (pg 10). Fold and tape this pattern to one of the 5-1/2 x 20 pieces of woods as shown in Figure 4 (pg 10). Trace the curve on the wood with a pencil or pen.

3. Tack nail these trough sides together. Using a band saw, scroll saw, or keyhole saw, cut along the curved line. This cuts both pieces at the same time, making them an identical matched set.

4. Cut Parts 2 to 6 according to Figure 1.

You have now finished rough cutting all the parts.

5. Sand the edges of the parts so that there is no danger of splintering.

You now have all the pieces cut to specifications. You should have

- 2 Part 1(tack nailed together)
- 1 Part 2 (made of sheet metal)
- 2 Part 3
- 1 Part 4
- 2 Part 5 (tack nailed together)
- 1 Part 6
- 1 Spacing block

Assembling the Parts

Use Figure 2 as a guide–pg 9

The Trough

6. Get both trough sides and the spacing block. Take one trough side and stand it up on its long flat side on top of the work bench. Butt the spacing block up against the trough side, being very careful to line up the centerline on the block with the centerline on the trough side. Tack nail the trough side to the spacing block.

7. Line up the other trough side at the other end of the spacing block and tack nail it. It is very important to line up the centerline on the spacing block with the centerlines on the trough sides.

8. Get the trough assembly and the prepared sheet metal piece. The easiest way to do this is to bend the sheet metal slightly so that only the center part touches when you first lay it down.

9. Using a small flat-headed nail, nail the sheet metal to the wood just at the center mark on each side. (If you want to, use Liquid Nails to glue the metal to the wood before nailing.) Working from the center of the curve and alternating from left to right, press the sheet metal down toward each end and use small flat-headed nails to secure the sheet metal to the wood at about 2-inch intervals along each side to within 2 inches of each end. Do not nail at the very ends; this portion will be secured later with screws through the finishing strips

10. Remove burrs from the edges of the metal sheet. Using black plastic tape (or duct tape), tape over the edges of the sheet metal along the curves to prevent sharp edges.

11. Remove the tack nails and spacing block from the assembly. Get the two finishing strips. Apply a coat of Liquid Nails to the flat surface of each one.

12. Place a strip on each end of the trough and secure it with screws as shown in Figure 2.

The Base

13. Assemble the base according to Figure 2.

Applying the Reflective Material

This procedure is very important and will determine how well your cooker will function. Clean the inside surface of the trough's sheet metal. The surface must be clean, dry, and free from dust, hair, or anything that will make a bump in the reflective film.

You can use any highly reflective material such as Hallmark gift wrap, aluminum foil, or self-adhesive aluminized Mylar film. We recommend self-adhesive Mylar because it is easiest to apply.

If you use the self-adhesive Mylar, cut two 10 x 13 pieces. Make sure the cuts are very straight and square, especially the 10-inch sides. We recommend using a straight edge and an X-Acto or hobby knife. Be sure to place the material on a flat surface when cutting with a knife. Make sure you use a surface that you don't care gets scored by the knife.

If you are using any other type of reflective material, cut six 10 x 4-1/2 pieces. This may also be cut using an X-Acto or hobby knife. If you are going to use this method, skip to step 20.

14. If you are going to apply self-adhesive material, get a spray bottle full of soapy water. (Use a few drops of liquid dish soap, just enough to make the water sudsy when you shake the bottle.) Spray the inner curved surface of the sheet metal until the surface has a fine mist of soapy water on it; see Figure 5 (pg 10).

15. Peel the backing off of the self-adhesive material. Be careful when you peel the backing off so that the material doesn't stick to itself. Then, beginning at the centerline in the middle of the bottom of the trough, carefully line up the 10-inch edge with the centerline on the sheet metal.

16. Gently lay the material into the trough. The soapy water will allow you to move the material around a little bit to position it correctly.

17. Avoid wrinkling or bubbling the material as much as possible when you first lay it down. Then, using the small roller and beginning at the center, roll the material smooth; see Figure 6 (pg 10). Repeat the process for the other side. Butt the pieces together at the bottom of the trough (it's okay if they overlap a little, but butted up is better).

18. You will have a little over an inch of material left sticking out of each end of the trough. Take this and wrap it over the wood finishing strips. Press firmly to ensure that the material adheres well. Trim any excess with a hobby knife or scissors. As extra protection against the end coming loose, you may use a piece of black plastic tape to secure the ends. Skip to section on *Completing the Trough.*

19. If you are using some other reflective material and rubber cement to hold it on, take one of the strips and apply a generous amount of rubber cement to the dull side. Make sure rubber cement is very liquid; you may need to thin it with rubber cement thinner.

20. You need to work fairly quickly because the rubber cement dries fast. Beginning at the centerline in the middle of the bottom of the trough, carefully line up the 10-inch edge with the centerline on the sheet metal. You will be able to slip the material around slightly to get it straight. Try to avoid wrinkling it as much as possible. When the strip is in straight, use the small roller to roll all the wrinkles out of it.

21. Apply glue to one strip at a time. Place that strip next to the previous on the trough (it's okay to overlap a little bit). Roll each one smooth before putting the next one on. Continue until all strips are in place.

22. You will have some material sticking out of each end of the trough. Apply a thin coat of rubber cement to each of the finishing strips and wrap the material over each one. Press firmly to ensure that the material sticks to the strips well. Trim off any excess with a hobby knife or scissors.

Completing the Trough

23. You will need to establish the locations of the clothes pins. Get the 1/4-inch diameter steam tube and attach the clothespins to it. Then, laying the tube across the narrow mouth of the trough, carefully line up the center of the tube with the centerline of the trough side. Lay the clothespin along the narrow edge of the trough side. Then, using a pencil and holding everything in place, trace around the clothespin. Do this for each side. When you mark the trough for both clothespins, apply a bead of white glue to the flat side of the clothespin and glue or screw it onto the trough in the location you traced. Hold it in position with tape until dry if you used glue.

You should now have a trough and a stand. If you wish to paint or varnish the wooden parts, now is the time to do it.

Final Assembly

24. Attach the parabolic trough to the base. If you are using carriage bolts, take one bolt and insert it from the inside of the trough through the side. Very gently tap it with a hammer to press the square part into the wood. Guide the bolt through one of the holes in the vertical supports. Put on a flat washer and a wing nut. Place a hex bolt, washer, and hex nut on the other side. Tighten the bolt finger tight.

If you use a hex bolt instead of a carriage bolt, place a star washer on the bolt *before* you push it through the trough side.

This completes the assembly of your Parabolic Trough Hot Dog Cooker.

The steam tube

1. Using the hacksaw or a tubing cutter, cut the copper tubing to a length of 18 inches.

2. File the ends to eliminate burrs.

3. If you have a flaring tool, you can flare out one end to make a minifunnel, which makes pouring the water in easier. If you don't have such a tool, use a pair of needle-nosed pliers to bend the edges out a little to form a little wider rim on that end.

4. Allowing for 12 inches of straight tubing between bends, slowly and carefully bend the ends of the tube to a 45° angle upward. Do the same for the other end (the bending will keep the water from running out of the tube).

5. Paint the tube with flat black paint and let it dry completely.

The hot dog skewer

1. Use a commercially available metal cooking skewer that can rest across the mouth of the trough. Cut it to the proper length.

How to test the model

Take the model outside on a sunny day and face it directly at the sun. As you begin to focus the model toward the sun, you will see the sun's rays strike along the inside edges of the trough. Position the trough toward the sun so that these rays converge on the center line. Use this technique to keep the trough focused on the sun while you are using it to cook hot dogs or making steam.

Try cooking the hot dog and making steam in the steam tube. Secure the skewer or steam tube in the clothespins on the trough sides and watch the results.

PARABOLIC TROUGH HOT DOG COOKER PARTS

Figure 1

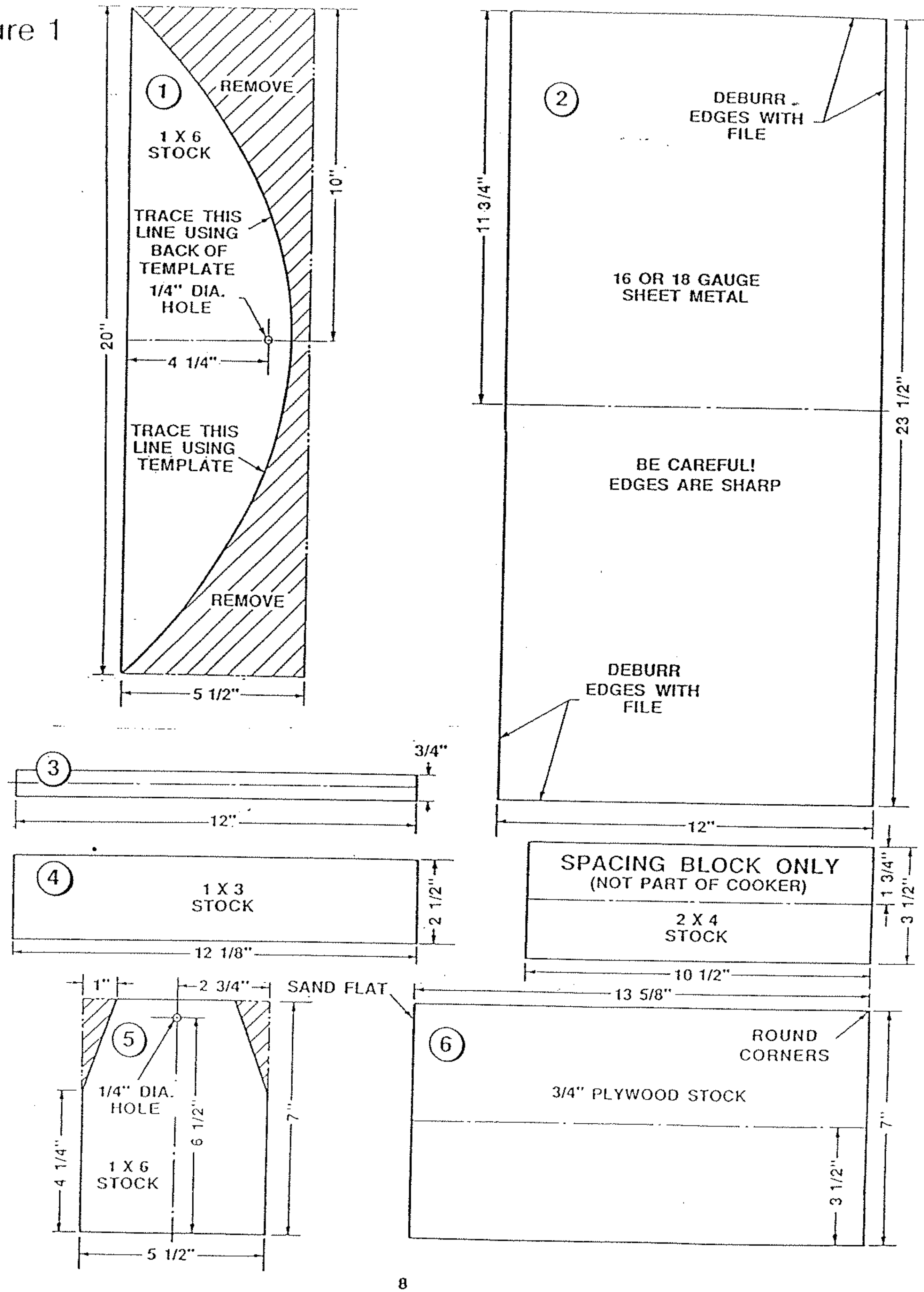


Figure 2

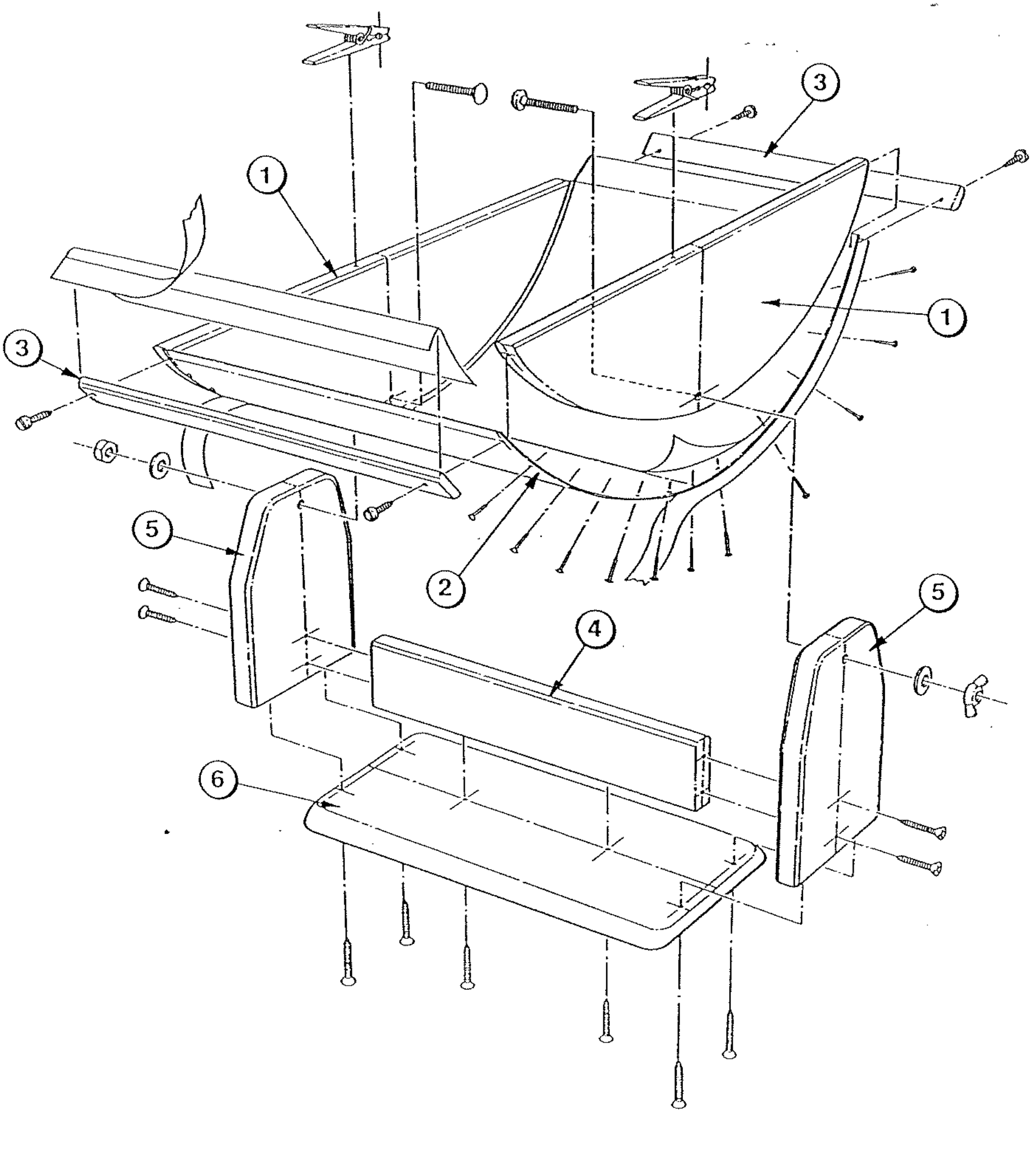


FIGURE 3

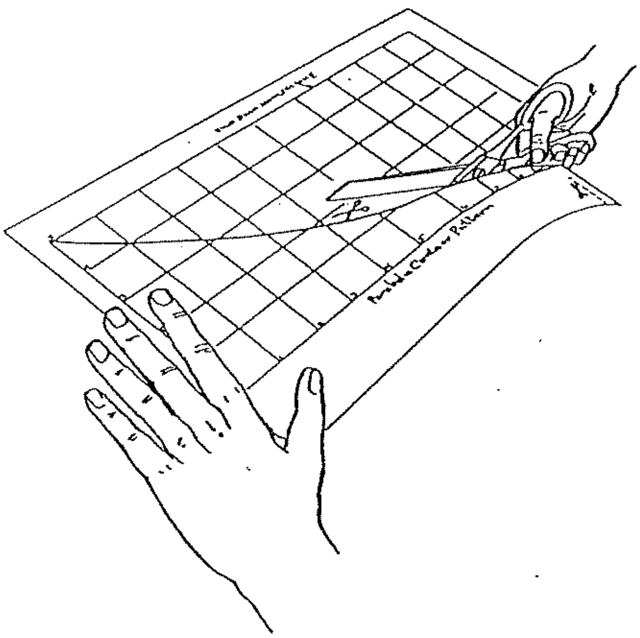


FIGURE 4

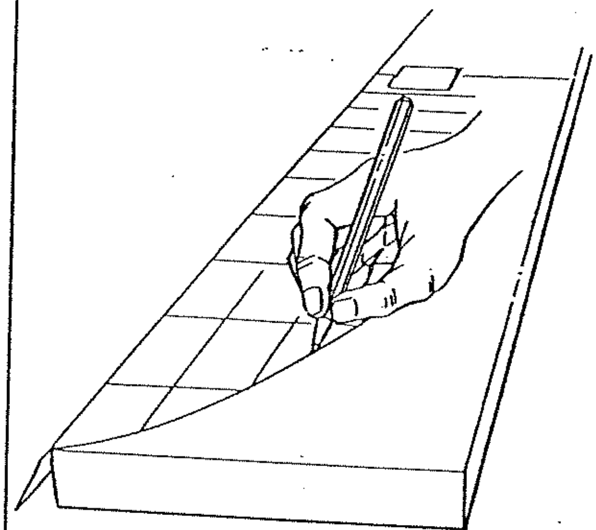


FIGURE 5

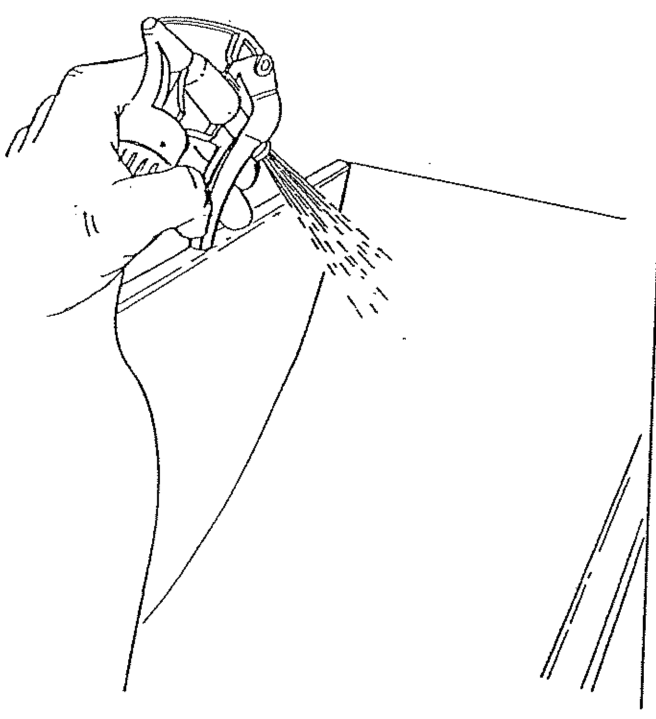
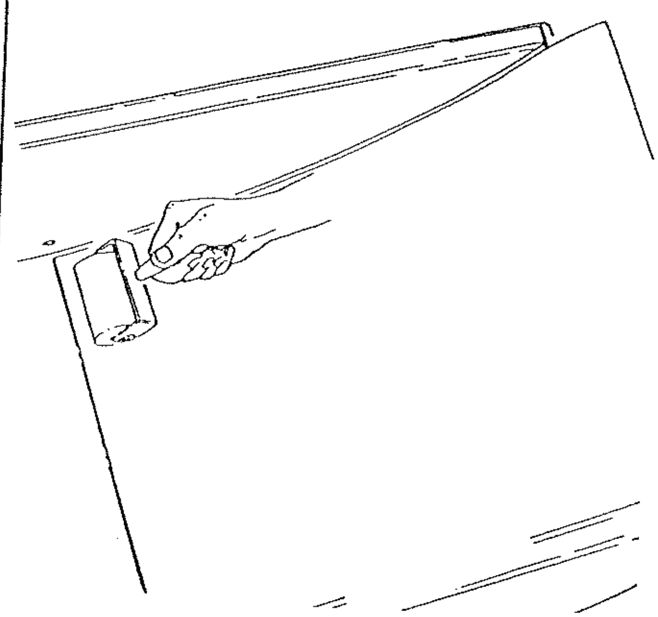
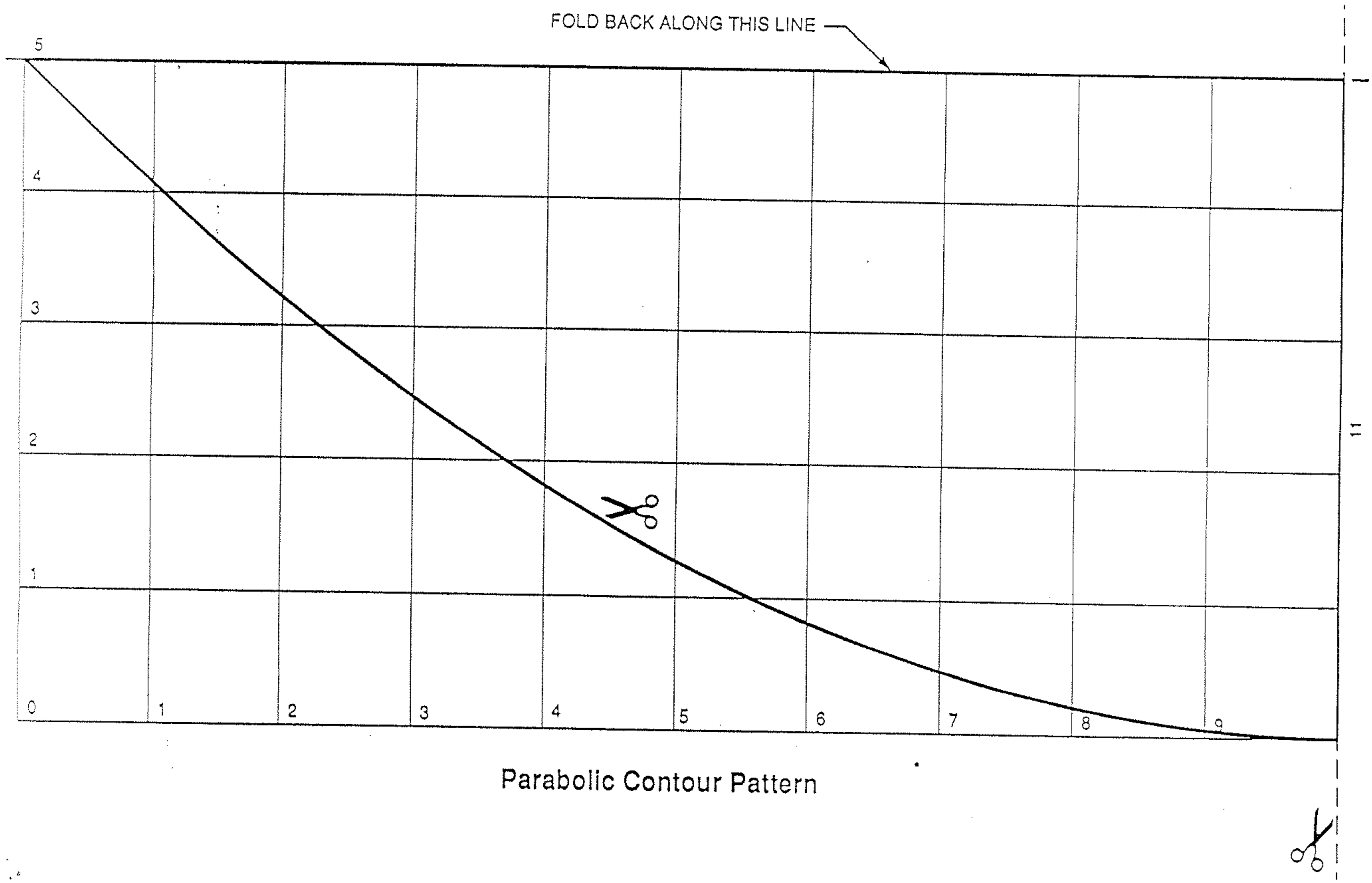


FIGURE 6





Parabolic Contour Pattern

Attachment: Parabolic Trough Template Program

The following program can be used to make parabolic templates for a hot dog cooker that are larger or smaller than the template given in the construction details.

The program is written in Applesoft BASIC for the Apple II series computers. It will also run on other personal computers that have BASIC interpreters or compilers, with some possible minor modifications.

The program will compute the points along a cross section of a parabolic surface for any given focal length. The focal length is the distance from the deepest part of the trough to the point where the rays of the sun converge. If the focal length is less than 8 and greater than 1.5, the program will produce a printer plot that can be used to make a template for the sides of the cooker. For other focal lengths, the (x,y) points are printed and can be transferred to plot paper by hand to make a template. In both cases, a hand-smoothed line must be run through the plotted points to form the curved part of the template.

The y values represent the distance in inches along the focal line. The corresponding x values run perpendicular to the focal length and represent the distance in inches away from the focal length.

The figure on the last page shows an example plot made by the program as well as a hand-smoothed line drawn through the plotted points. The focal length in this example is 4 inches. This template is ready to be used to cut out the sides of the solar cooker.

Also notice that the (x,y) points representing the parabolic surface are printed before the plot. The user can choose the number of these values to print. If the surface is to be plotted by the computer (1.5 < focal length < 8), then only a few (x,y) values are needed because the plot is not affected by the number of points chosen. However, if the surface points are to be hand plotted, then more points may be needed to ensure that a smooth surface can be drawn. This is particularly important with a very large focal length.

To use this program, follow these steps:

1. Make sure that your printer is plugged into slot one or your printer port of your computer. To produce accurate plots, you must use a printer that prints 6 lines per inch and 10 characters per inch. (The program will compute the (x,y) values regardless of the printer type or whether one is plugged in or turned on).

2. Boot Applesoft BASIC on your computer and type in the program exactly as shown in the listing.

3. Save the program by inserting a DOS formatted floppy disk, typing SAVE PARAB, and pressing the return key.

4. Execute the program by typing RUN and pressing the return key.

NOTE: For a printed copy of the values or a plot (or both), turn on the printer. If you do not have a printer, you must copy the (x,y) values printed on the screen to paper. The control-s key combination can be used to pause and resume the screen listing. The program will also allow you to repeat the screen listing.

5. Follow the directions in the program.

6. To run the program again while the program is still loaded, repeat step 3.

NOTE: To run the program at a later time (after the computer has been rebooted), insert the floppy disk that contains the PARAB program, type RUN PARAB, and press the return key.

Nicolas Menicucci wrote the program and donated it for use in this project. For free consultations about this program, call Nicolas at (505) 842-6330 or write to him at 1521 San Carlos, SW, Albuquerque, NM, 87104.

PARABOLIC TROUGH TEMPLATE PROGRAM

(Nicolas Meniccuci)

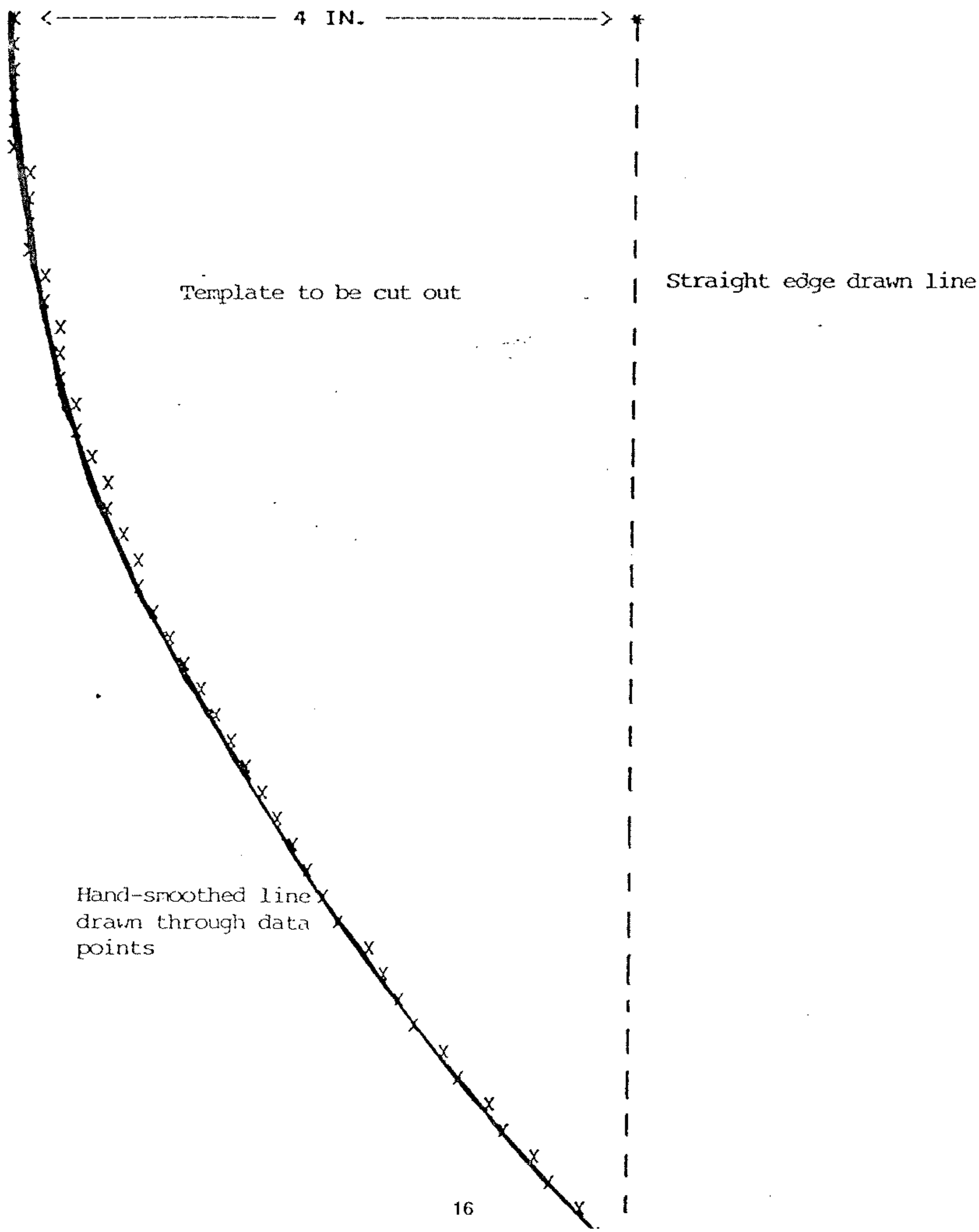
```
10  DIM XVL(100),YVL(100)
20  ONERR  GOTO 660
30  GOSUB 700
40  REM  PROGRAM BY NICOLAS MENICUCCI
50  PRINT : PRINT
60  INPUT "INPUT FOCAL LENGTH (INCHES)  > ";FOC
70  INPUT "INPUT # X,Y VALUES (MAX=100) > ";IT
80 TI = FOC / (IT - 1)
90  HOME
100  REM  PRINT TO SCREEN
110  PRINT : PRINT  TAB( 7);"XVAL"; SPC( 3);"YVAL"
120  PRINT  TAB( 7);"----"; SPC( 3);"----"
130  PR# 1: REM  PRINT TO PRINTER
140  PRINT : PRINT  SPC( 6);"XVAL"; SPC( 3);"YVAL  FOCAL POINT = ";FOC
150  PRINT  SPC( 6);"----"; SPC( 3);"----"
160  PR# 0
170 YV = 0
180  REM  *** SET UP LOOP ***
190  FOR I = 1 TO IT
200 X = 4 * FOC * YV
210 XV =  SQR (X)
220 VRBL = XV: GOSUB 460:XVL(I) = OUT
230 VRBL = YV: GOSUB 460:YVL(I) = OUT
240  REM  PRINT TO SCREEN
250  PRINT I;")"; TAB( 7);XVL(I); TAB( 14);YVL(I)
260  REM  PRINT TO PRINTER
270  PR# 1
280 LI = (I > 9) + (I > 99)
290 LD =  LEN ( STR$ (XVL(I)))
300  PRINT I;")"; SPC( 4 - LI);XVL(I); SPC( 7 - LD);YVL(I)
310  PR# 0
320 YV = YV + TI
330  NEXT I
335  PR# 1: PRINT : PRINT : PR# 0
340  PRINT : PRINT "FOCAL POINT = ";FOC
350  PRINT
360  PRINT "SEE VALUES AGAIN (Y/N--CAPS ONLY) ? ";
370  GET AG$: PRINT AG$
380  IF AG$ = "Y" THEN  HOME : GOTO 110
390  IF AG$ <  > "N" GOTO 360
400  GOTO 490
410  REM   *** CHANGE A # TO 2 DECIMAL PLACES ***
460 OUT =  INT ((VRBL * 100) + .5) / 100
470  RETURN
480  REM  *** PRINTER PLOT ***
490  IF FOC >  = 8 OR FOC < 1.5 THEN  HOME : PRINT "FOC LENG OUT OF RANGE": ENI
```

```
500  PR# 1
510 DASHS = ((FOC * 10) - (5 +  LEN (" " +  STR$ (FOC) + " IN. "))) / 2
515  IF DASHS = 0 THEN  PRINT "X <";: GOTO 530
520  PRINT "X <";: FOR J = 0 TO DASHS - 1: PRINT "-";: NEXT
530 DASHS = DASHS - .5: IF DASHS <  = 0 THEN  PRINT " ";FOC;" IN. ";: GOTO 550
540  PRINT " ";FOC;" IN. ";: FOR J = 0 TO DASHS: PRINT "-";: NEXT
550  PRINT "> *"
560  FOR I = 1 TO FOC * 2 * 6
570 NCH = I / 6
580 Y = (NCH ^ 2) / (FOC * 4)
590 YP =  INT ((Y * 10) + .5)
600 XP = I
610  PRINT  SPC( YP);"X"
620  NEXT
630  PR# 0
640  HOME : END
650  REM   *** ERROR HNDLR ***
660  HOME
670  PRINT "ERROR! STOPPED--TYPE 'RUN' TO RE-RUN"
680  STOP
690  REM   *** INTRO ***
700  HOME
710 PGM$ = "PROGRAM TO CALCULATE PARABOLIC SURFACE"
720  HTAB 20 - ( LEN (PGM$) / 2): PRINT PGM$
730  PRINT :BY$ = "WRITTEN BY: NICOLAS MENICUCCI"
740  HTAB 20 - ( LEN (BY$) / 2): PRINT BY$
750  PRINT :PC$ = "FOR HARD COPY TURN PRINTER ON"
760  HTAB 20 - ( LEN (PC$) / 2): PRINT PC$
770  RETURN
```

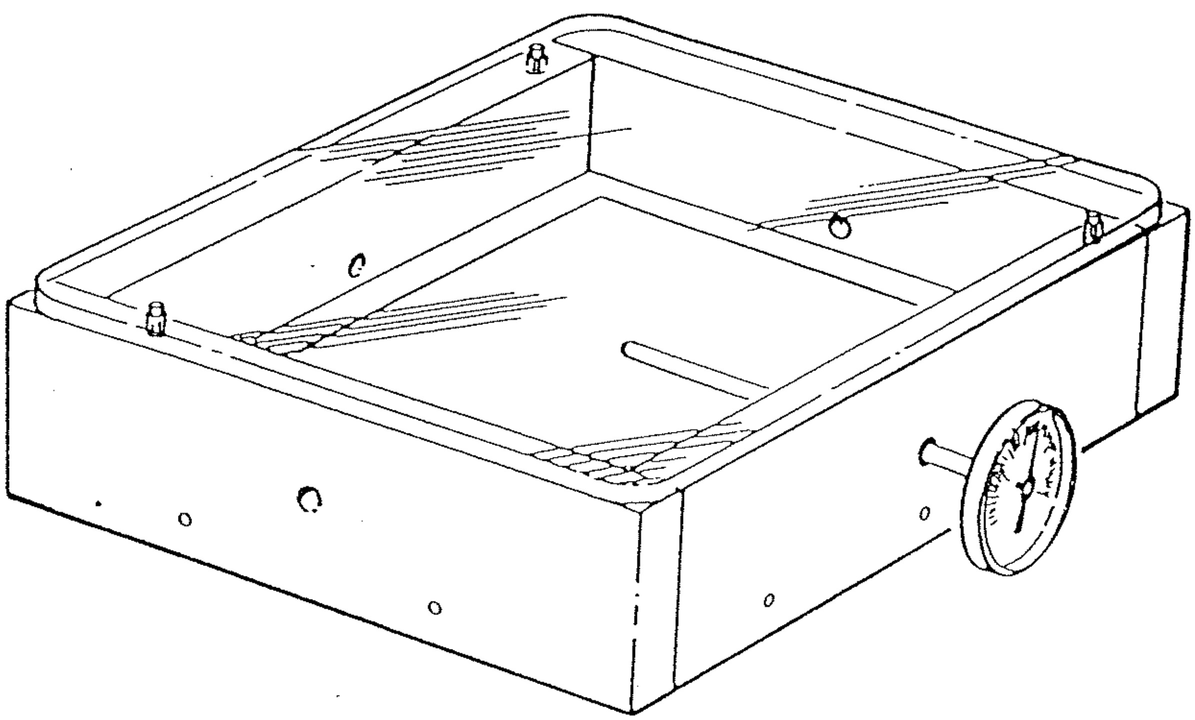
TROUGH PROGRAM OUTPUT EXAMPLE

FOCAL POINT = 4

	XVAL	YVAL
1)	0	0
2)	2.67	.44
3)	3.77	.89
4)	4.62	1.33
5)	5.33	1.78
6)	5.96	2.22
7)	6.53	2.67
8)	7.06	3.11
9)	7.54	3.56
10)	8	4



How to Build the Flat Plate Solar Collector Model



Sandia National Laboratories

Background

The small plastic-covered models demonstrate flat plate solar collectors. The model consists of a simple wooden open-top box, a transparent top, and a painted slab of metal (black on one side, white on the other).

For the classroom exercises, you will also need a metal meat thermometer that can measure temperature in the range of about 50°F to 180°F. To do all the experiments in the classroom exercises, you will have to construct a total of 4 collectors because Experiment 1 calls for 2 collectors, and Experiment 3 calls for 4 collectors.

How it works

The transparent top allows the sun's rays into the box. When the sun's rays strike the metal plate, the metal plate heats up. This heat is then trapped inside the box by the transparent top. You can measure this heat buildup over time with the thermometer.

What you will need to build it

Materials

4-quarter or 1-inch (nominal) thick pine or any medium hardness wood that is easy to cut

Wood screws or nails

Construction glue (optional)

A piece of any clear plastic material (Plexiglass, for example) that is less than 5/16 inch thick

A piece of thin flat metal no less than 1/8 inch thick (scrubbed with sandpaper or steel wool so that it can take the paint) with no sharp edges

Any medium- to high-temperature flat enamel paint, black and white (can also use black and white auto paint if you have any to spare)

Tools

Saw or table saw

Hammer or screwdriver

1- to 3-inch paint brush, roller, or foam rubber brush

How to build it

1. Cut the pieces as shown in Figure 1 (pg 5).

2. Construct the box as shown in Figure 2. You may glue, screw, or nail the box together. You should paint the box a light color or white.

3. Drill 1/4-inch holes in the side (1, 2, 3, or 4 holes) to allow the thermometer(s) in.

4. In a well-ventilated area, paint the metal slab black on one side and white on the other according to the paint manufacturer's directions (allow each side ample time to dry).

5. Line up the holes in the transparent top with the finishing nails that you placed on the box as shown in Figure 2 (pg 6) and place the top on the box (these nails keep the top from sliding off during tests): you are now ready to use the model.

How to test the model

Place the box outside on a sunny day and insert one or more thermometers through the hole(s). Make sure that the thermometer fits under the metal plate and that it can be read easily. Tip the model up about 30° from the ground: make sure that the top is properly secured on the nails and does not slide off.

Figure 1

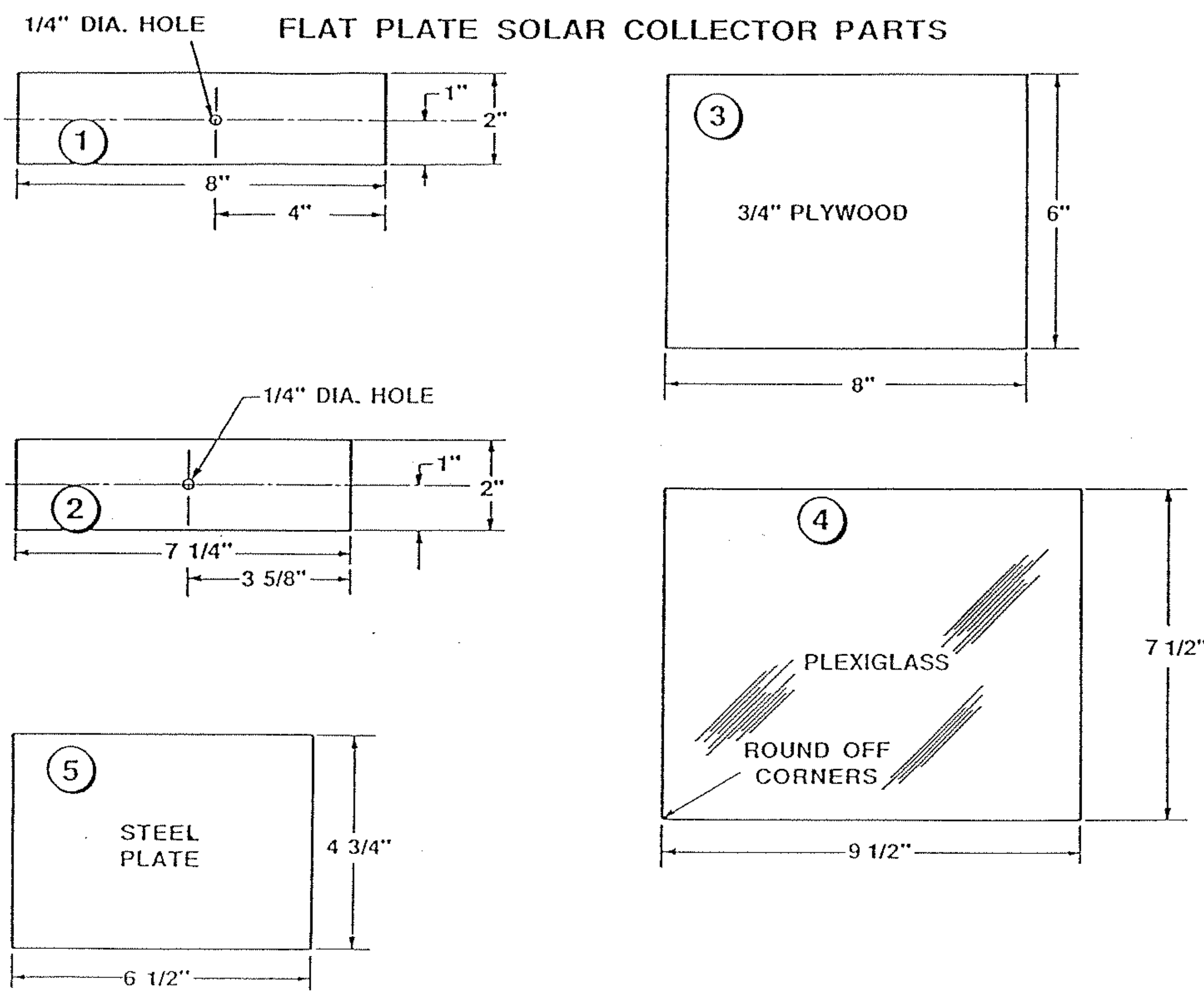
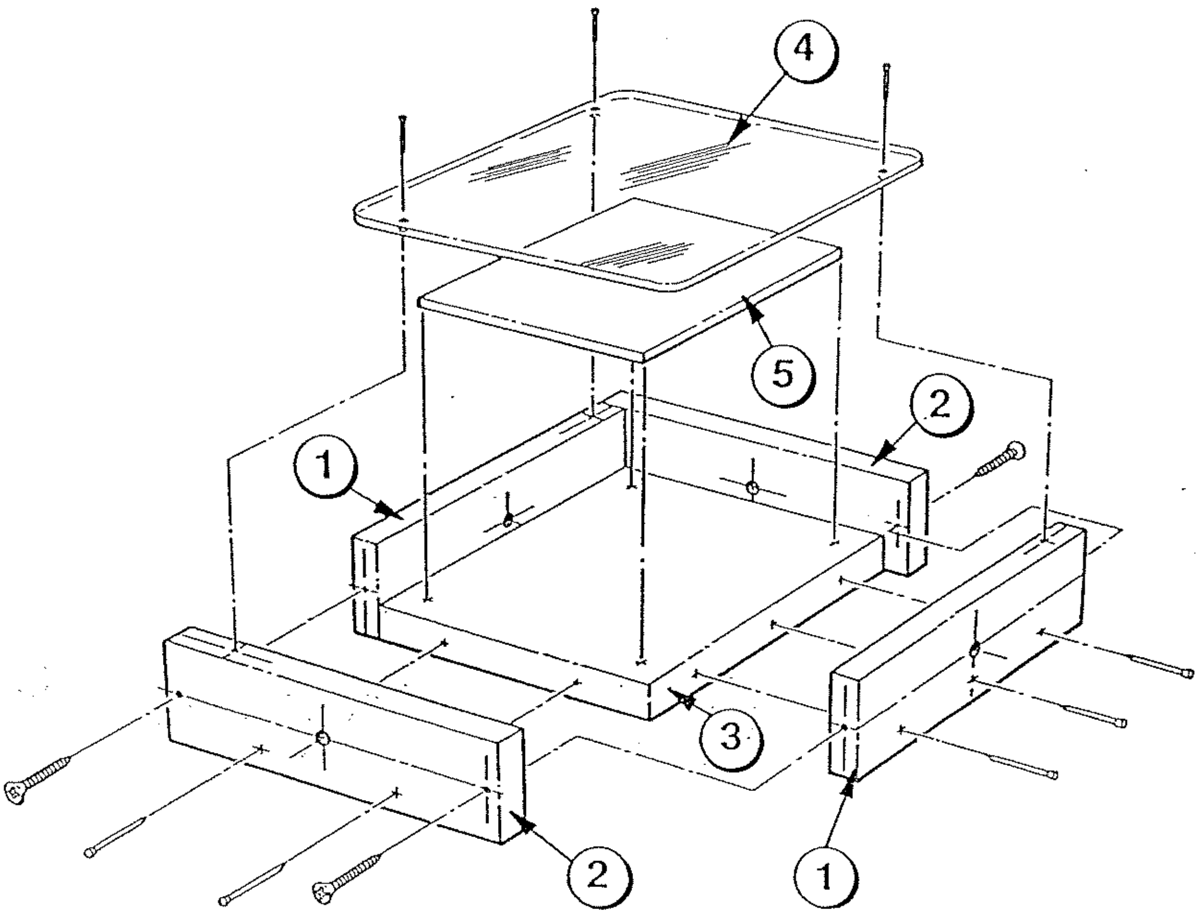
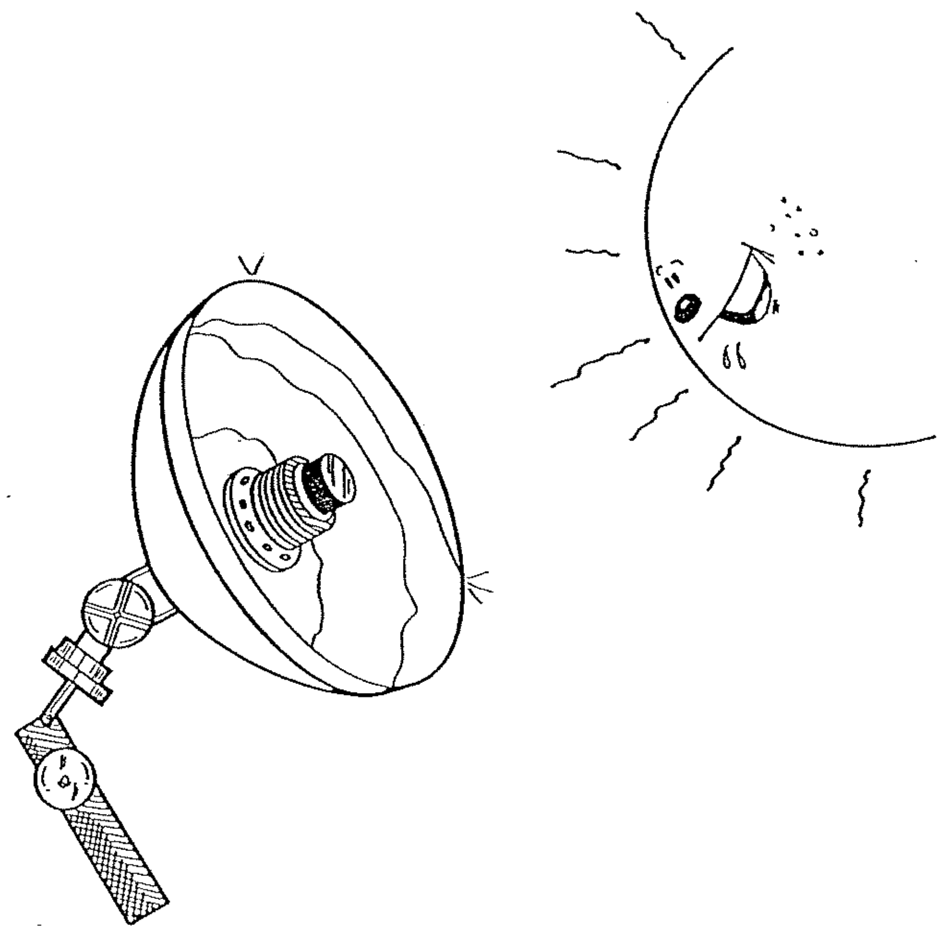

1/4" DIA. HOLE
FLAT PLATE SOLAR COLLECTOR PARTS
1
1"
2"
8"
4"
3
3/4" PLYWOOD
6"
8"
1/4" DIA. HOLE
2
1"
2"
7 1/4"
3 5/8"
4
PLEXIGLASS
ROUND OFF
CORNERS
7 1/2"
9 1/2"
5
STEEL
PLATE
4 3/4"
6 1/2"

Figure 2



How to Obtain the Dish/Stirling System



Sandia National Laboratories

Background

This dish/Stirling system demonstrates a parabolic reflective dish concentrator. The model consists of a metal dish with a Stirling engine at the focal point. The engine's shaft is connected to a flywheel, which will turn when the engine is heated with concentrated sunlight.

How it works

When you aim the dish directly at the sun on a clear day, the reflective surface of the dish reflects the sunlight to a single point on the engine's heater head. When the heater head is warmed, it causes a gas inside the engine to expand and push on a piston. The piston is connected to a crank that is, in turn, connected to the flywheel. It takes 30 to 40 seconds of solar heating to warm the engine before it will run. After the engine is heated, the operator turns the flywheel by hand to get it started.

Where you can purchase the Dish/Stirling System

The only known source for this product is

Edmund Scientific Co.
Edscorp Building
Barrington, NJ 08007-1380
(609) 547-8880
Part #80311, Solar Stirling Cycle